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Drone-Induced Midfacial Blast Injuries: Early Reconstruction and 5-Year Outcomes from a Single-Center Cohort

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Abstract

Background: Modern warfare has introduced novel mechanisms of injury, particularly drone-induced blast trauma, resulting in complex craniomaxillofacial injuries. These injuries differ substantially from traditional ballistic trauma and require adapted surgical strategies. This study aimed to evaluate the clinical characteristics, management approaches, and long-term outcomes of midfacial blast injuries. **Methods:** A retrospective analytical study was conducted on 41 patients with drone-induced midfacial blast injuries treated at a tertiary referral center in Armenia following the 2020 Nagorno-Karabakh war. All patients underwent surgical management after initial stabilization and were followed for 5 years. Clinical outcomes, complications, and reconstructive needs were assessed. **Results:** All patients presented with comminuted midfacial fractures, frequently associated with polytrauma (87.8%). Burns were observed in 82.9% of cases. Surgical management included radical debridement and early definitive osteosynthesis using titanium fixation systems. No cases of postoperative osteomyelitis, bone sequestration, or implant failure were observed during the 5-year follow-up. Patients with extensive soft tissue defects, particularly nasal and lip amputations required multiple reconstructive procedures. Long-term follow-up revealed progressive soft tissue thinning over titanium meshes, especially in the zygomatico-orbital region, necessitating secondary interventions such as lipofilling. **Conclusions:** Drone-induced midfacial blast injuries represent a distinct and severe form of trauma. Early definitive reconstruction following adequate debridement was associated with favorable outcomes. However, soft tissue reconstruction remains challenging and often requires staged procedures. Long-term follow-up is essential to manage delayed complications and optimize aesthetic outcomes.

Keywords: drone injuries; blast trauma; midfacial fractures; craniomaxillofacial trauma; osteosynthesis; facial reconstruction; military medicine

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Introduction

Current geopolitical tensions have increased the risk of high-intensity military conflicts and state-to-state wars [1].

Recent advancements in military technology have significantly altered the patterns of trauma encountered in modern warfare. In particular, the widespread use of unmanned aerial vehicles (UAVs), especially explosive drones, has introduced a distinct category of high-energy blast injuries

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[2–4]. These injuries differ fundamentally from traditional ballistic trauma due to the combined effects of blast waves, fragmentation, thermal injury, and secondary projectiles [1,3,5].

The management of cranio-maxillofacial trauma (CMFT) in war-torn nations presents formidable challenges precipitated by limited resources, damaged infrastructure, and a dearth of skilled surgical professionals [6]. Injuries to the craniofacial region are of particular concern due to the high density of critical anatomical structures, including the airway, major vascular pathways, sensory organs, and functionally important soft tissues [1].

Midfacial trauma in this context presents unique diagnostic and therapeutic challenges. The combination of comminuted fractures, extensive soft tissue loss, orbital and cranial injury, contamination, and compromised vascularity—often exacerbated by delayed evacuation or suboptimal initial care—complicates both acute management and reconstructive planning [7]. Despite the growing prevalence of such injuries, the current literature remains limited in systematically characterizing their clinical features and in defining optimal management strategies, particularly for head and neck involvement. Most existing studies focus on traditional ballistic trauma or generalized blast injuries, with insufficient emphasis on the specific injury patterns and reconstructive challenges associated with modern drone-related mechanisms.

To our knowledge, this is one of the first studies specifically addressing long-term outcomes of drone-induced midfacial blast injuries.

The aim of this study was to analyze the clinical features, surgical management, and long-term outcomes of midfacial blast injuries in a cohort of patients treated during a recent military conflict.

Material and Methods

2.1. Study Design and Setting

This retrospective analytical study was conducted at the Department of Otorhinolaryngology and Maxillofacial Surgery in <<Heratsi>> hospital, Yerevan, Armenia. The wounded military patients of the 2020 Nagorno-Karabakh war treated between September and November 2020 were included in study. This research was conducted in accordance with relevant ethical standards, and the study protocol was approved by the Yerevan State Medical University Ethics Committee [IRB Expert Conclusion No. 05/2026].

Ethical considerations

Ethical considerations were accounted for throughout the study, and the patients' names and medical information were kept completely confidential. The medical histories of the patients were used solely for the purposes of the current study.

Patient Selection

The inclusion criteria were: drone-induced blast injuries involving the midface; availability of complete medical records and 5-year follow-up data. The exclusion criteria were: injuries due to non-blast mechanisms (e.g., gunshot wounds, blunt trauma); isolated soft tissue injuries without midfacial skeletal involvement; incomplete data or loss to follow-up.

Study Population

A total of 43 patients were initially identified. After applying eligibility criteria, 41 patients were included in the final analysis. All patients were male, aged 18–46 years (mean: 25.3 years).

Injury Characteristics

Comminuted midfacial fractures were observed in 41 patients. Associated mandibular fractures were present in 11 (26.8%; n=41) cases. (Table 1) Combined scull-base injuries were present in five (12.2% n=41) patients. Four patients had severe orbital injuries requiring evisceration. Additional injuries included nasal amputation (n = 2), lips defects (n = 3), and facial burns of varying severity (n = 12). 36 patients have combined and multiple (polytrauma) injuries. All patients exhibited signs consistent with blast-related acoustic neuritis.

Table 1. Distribution of midface fractures combined and comminuted injuries.

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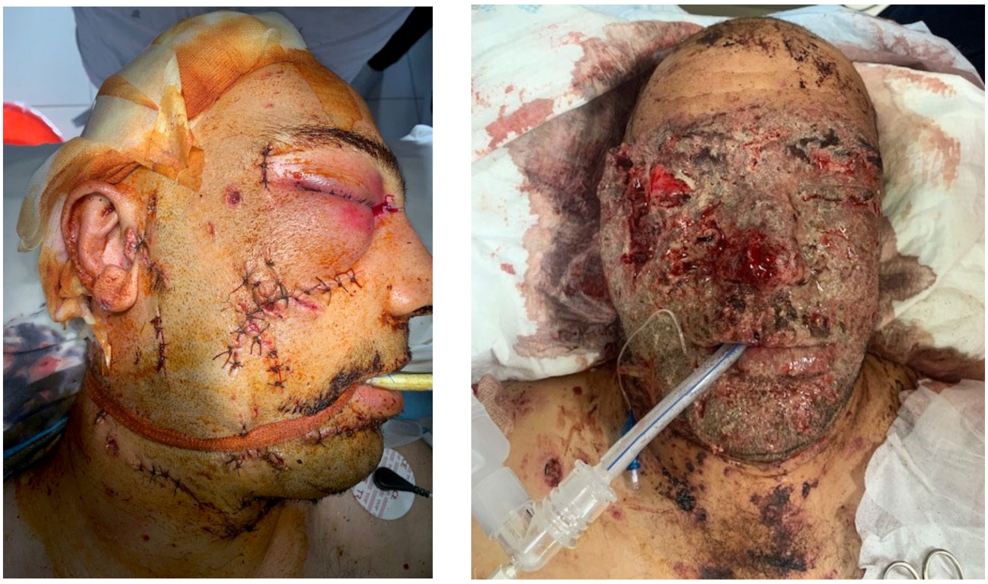
Midface fractures combined and comminuted injuries (n=41)	N (%)
Skull base fracture	5 (12.2%)
Mandible fracture	11 (26.8%)
Eye ball injury, with evisceration	4 (9.8%)
Extremities injuries	32 (78%)
Thoracic or other trunk injuries	4 (9.8%)
Burns	34 (82.9%)

Triage and Surgical Management

Multiple drone-related explosions is related to mass casualty incident (MCI), which was required exceptional emergency arrangements, such us triaging patients with the priority being stabilization of acute life-threatening injuries by controlling hemorrhage and securing the airway and diverting to the distant hospitals. Pre-hospital care was well-organized for effective medical support system in combat operations. So, the wounded patients were transported as soon as feasible from the site of injury to the most appropriate care facilities for provided sooner emergency appropriate care (i.e., bleeding control, advanced resuscitative and damage control surgery). Accordingly, patients underwent primary surgical wound debridement and initial hemodynamic stabilization, damage control surgery in field hospital settings or nearest medical treatment facilities. After the tactical and strategic medical evacuation of wounded personnel the specialized surgical care was organized at tertiary referral centers of safe locations outside the theater. So, our hospital was one of the final destinations of strategic evacuation. All this patients after admission to our hospital were at first hospitalized in ICU (Figure 1). Very important note, that at the time of hospital admission all wounded patients were provided by the references, included information of all examinations, treatment tools, surgical interventions, vaccinations ets., which was performed on medical evacuation (MEDEVAC) stages.



(a) (b)

Figure 1. Initial clinical presentation of a patient with severe comminuted midfacial blast injury upon admission to the intensive care unit: (a) drone-blast injured patient admitted with primary surgical wound debridement, initial hemodynamic and respiratory stabilization; (b) drone-blast injured patient with severe III^{0}-IV^{0} burns admitted with primary surgical wound debridement, initial hemodynamic and respiratory stabilization.

From 41 patients with comminuted midfacial blast injuries 17 (41.5%; n=41) were admitted intubated under mechanical ventilation. All patients underwent surgical treatment following initial stabilization. The timing of surgical management was influenced by injury severity, surgical urgency, and the presence of concomitant injuries (included thoracic trauma and traumatic brain injury), which required continuous monitoring and hemodynamic stabilization. It is important to note that, as military operations took place during the COVID-19 pandemic, all hospitalized wounded patients were routinely screened for the virus. Patients with positive test results were isolated in dedicated intensive care units. In COVID-19-positive cases, chest computed tomography (CT) was performed systematically, and in the presence of pneumonia, appropriate treatment was initiated. Whenever feasible, surgical intervention was postponed until clinical stabilization.

Among patients with facial skeletal injuries, only one patient tested positive for COVID-19 in the preoperative period and remained asymptomatic. Following a negative test result one week later, the patient subsequently underwent surgical treatment. Generally, the time period between hospitalization and operation ranged from several hours to seven days. Management included radical debridement of necrotic tissues, final rigid osteosynthesis, and reconstruction of bone defects using titanium plates and meshes where required. The reconstructive strategy was individualized based on defect extent and tissue condition (Figure 2, 3).

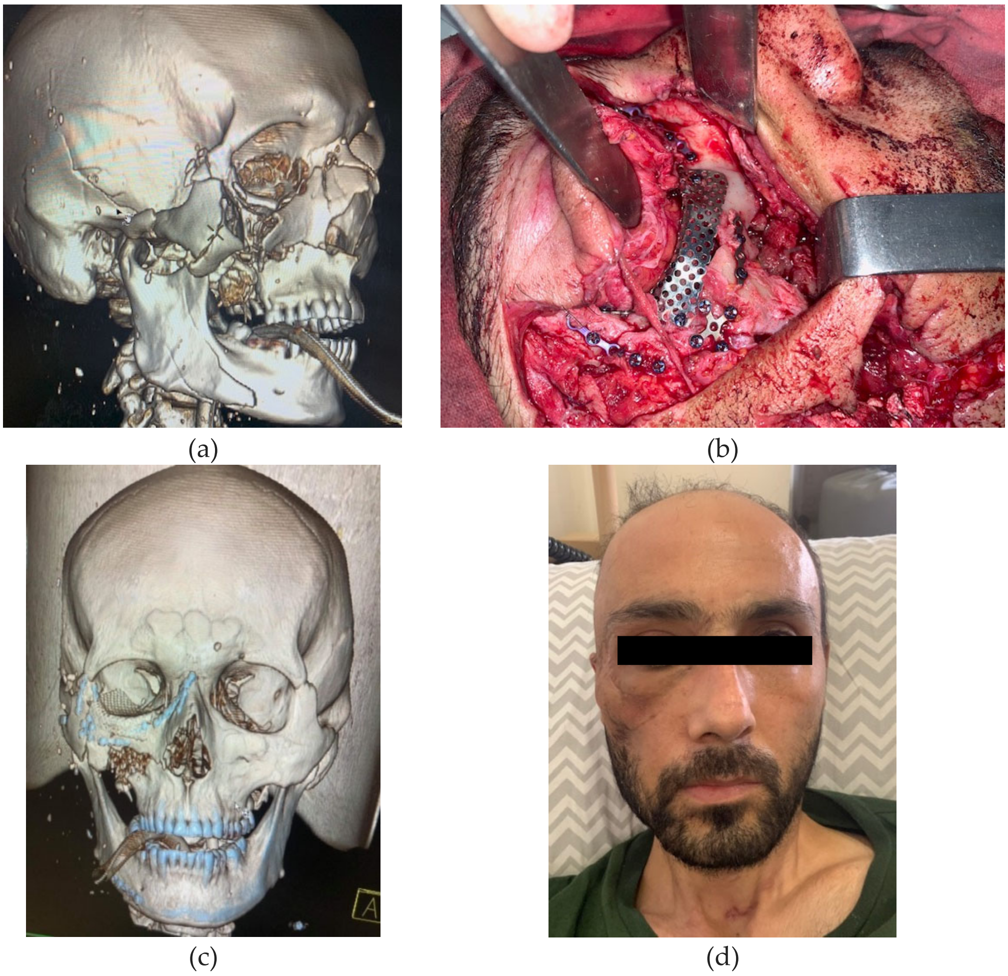


Figure 2. Drone-blast midfacial injury: (a) 3D CT scan demonstrates right site severely comminuted midface fracture; (b) early definitive osteosynthesis and blow-out reconstruction using titanium mesh and plates; (c) postoperative 3D CT scan; (c) long-term (5 years follow-up) postoperative result demonstrating soft tissue thinning over titanium mesh and plates in the right zygomatic region.

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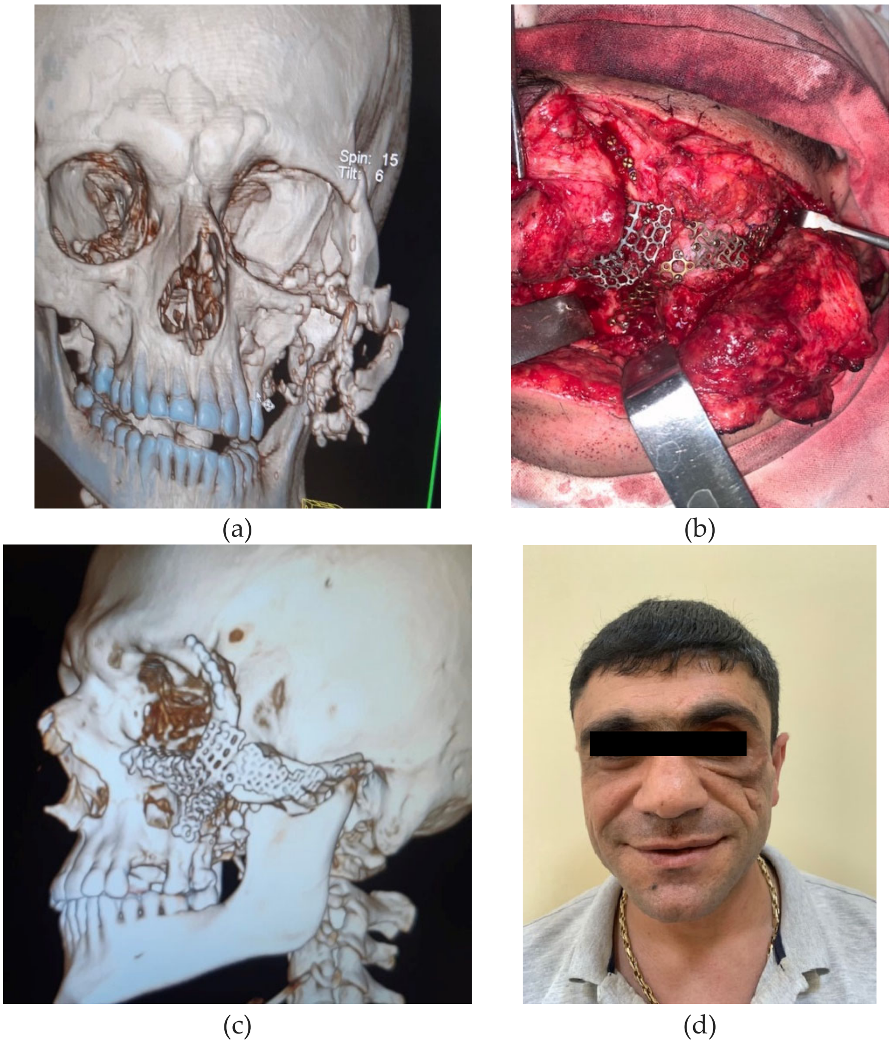

Figure 3. Drone-blast midfacial injury: (a) 3D CT scan demonstrates left site severely comminuted midface fracture; (b) early definitive reconstruction osteosynthesis using titanium mesh and plates; (c) postoperative 3D CT scan; (c) long-term (5 years follow-up) postoperative result demonstrating soft tissue thinning over titanium mesh and plates in the left zygomatic region.

Follow-Up and Outcomes

Patients were followed for 5 years postoperatively. Outcome measures included structural stability, wound healing, complications, functional recovery, and aesthetic results. Secondary procedures were recorded.

Statistical Analysis

Descriptive statistics were used to summarize clinical data. Continuous variables are presented as mean values, and categorical variables as frequencies and percentages. In addition to descriptive statistics, subgroup analyses were performed to explore associations between injury characteristics and clinical outcomes. Categorical variables were compared using the chi-square test or Fisher's exact test where appropriate. A p-value < 0.05 was considered statistically significant. Statistical analyses were performed using SPSS, version XX (IBM Corp., Armonk, NY, USA).

Results

Postoperative Outcomes and Complications

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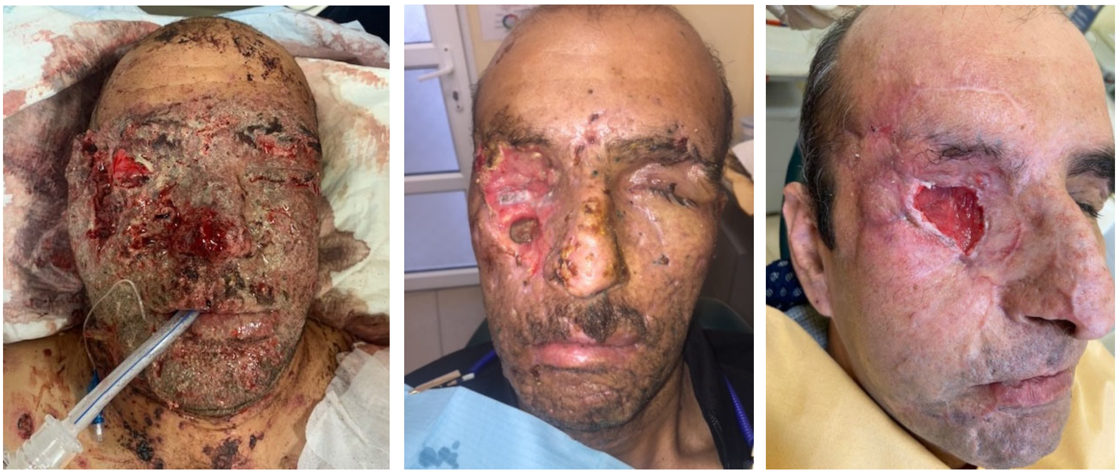
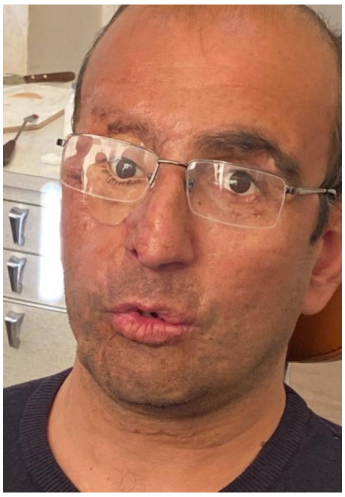
Burn-associated injuries were associated with delayed healing and required prolonged wound care, including healing under iodoform gauze dressings, surgical necrectomy, and local flaps reconstruction. (Figure 4).



(a) (b) (c)



(d)

Figure 4. Burn-associated soft tissue injury with delayed healing requiring necrectomy and local flap reconstruction: (a) drone-blast injured patient with severe III$^{\circ}$-IV^{0} burns and comminuted right site midface fracture; (b) one month follow-up after wound debridement, left eye evisceration and right eye enucleating and zygomatico-orbital osteosynthesis, healing under iodoform gauze; (c) 3 months follow-up after multiple local soft tissue flaps reconstruction; (d) patient with prosthetic rehabilitation after 5 years follow-up.

Subgroup analysis was performed to evaluate the impact of burn injuries and soft tissue defects on clinical outcomes (Table 2).

Patients with burn injuries demonstrated a significantly higher incidence of delayed wound healing compared to those without burns ($p < 0.05$). These patients more frequently required prolonged wound care and secondary reconstructive procedures.

Similarly, patients with extensive soft tissue defects (nasal and perioral regions) required significantly more staged reconstructive interventions compared to patients without such defects ($p < 0.05$).

No statistically significant differences were observed in the rates of postoperative infection or implant-related complications between subgroups.

Table 2. Comparison of Clinical Outcomes Based on Injury Characteristics.

Clinical course	Burn Group (n=34)	No Burn (n=7)	p-value
Healing time (range, median)	12-60 days (17.5±1.2)	7-10 days (8.7±0.4)	<0.05
Secondary procedures or surgeries	28	1	<0.05
Infection	None	None	NS

Four patients (9.7%; n=41) had undergone evisceration because of eyeball severe injury, one of them both eyes evisceration. No cases of postoperative osteomyelitis or bone sequestration were observed during the 5-year follow-up. All fractures reconstructions demonstrated stable outcomes without implant-related infection or failure. The patients with nasal amputation and lips large defect required more surgical interventions for functional and esthetic reconstruction.

The long-term outcomes (5 years) have demonstrated progressive thinning of soft tissues over titanium meshes resulting in aesthetic imbalance especially in the zygomatico-orbital zones. Figures 2 (d), 3 (d).

Secondary procedures, including lipofilling, were required to restore soft tissue volume and improve facial symmetry in selected cases.

Discussion

Current geopolitical tensions have increased the risk of high-intensity military conflicts and state-to-state wars [1]. On Sept 27, 2020, Azerbaijan initiated a large-scale war against Nagorno-Karabakh. As a result of these unrelenting attacks, large numbers of people have been wounded and require medical care, which has put the Armenian and Nagorno-Karabakh health-care systems under unprecedented pressure. This strain has forced many of the existing COVID-19 centers to shift their scope, and most non-emergency medical care has either been delayed or cancelled [8].

Unmanned aircraft systems (UAS), commonly known as drones, are part of a new and budding industry [4]. The extensive use of explosive ordinance dropped by drones targeting mass casualties and predisposes to blast and shrapnel injuries to the areas of the body exposed from trench warfare—often the head, neck, upper limbs, and the face [9,10].

Facial combat injuries are high-energy, war related maxillofacial traumas resulting from blast, ballistic, or fragmentation mechanisms, typicaly characterized by combined osseous and soft tissue destruction, contamination, and frequent association with multisystem injuries. They are injuries which causing cosmetic, functional, and psychological damage [11]. As noted Wordsworth and coauthors. (2017) 75% of blast injury casualties survived and the explosive devices was the most common mechanism of injury with the mid-face the most commonly affected facial region [12]. In blast injuries a facial fracture was a significant marker for increased total injury severity score [3,12]. The increasing of incidence and of mid-facial injuries is reported by many authors. Keller et al., (2015) reported the overall incidence of head and neck trauma in modern combat has increased from 6% to 21% in early conflicts (e.g., World War II and the Korean War) to 21% to 43% in more recent conflicts (e.g., the Somali civil war, Operation Iraqi Freedom, and Operation Enduring Freedom) [13]. In contrast, during the Syrian Civil War, 66.3% of trauma casualties were caused by gunshot wounds and 31.3% by blast injuries, with facial injuries being the second most common type after extremity injuries [14].

Prysiazhniuk O et al., (2025) has reported the primary cause of war-related maxillofacial injuries in Russo-Ukraine war was high-energy blast trauma resulting from artillery strikes, mines, drones, rocket attacks, and bombings. War-related military trauma involved soft tissue damage in 97.1% of cases [3]. This is in accordance with presented data, as only 2 cases of gun-shot injury were hospitalized in our department and these patients were not included in a study.

Efficient and well-structured medical evacuation of the wounded represents a key component in ensuring effective medical care during mass casualty situations and military operations [7,15]. The military medical evacuation (MME) system is an intricate network of interconnected systems provides a range of medical treatments from the point of injury (POI) to healthcare facilities in the home country or another secure place outside of the joint operations area [15,16]. The MME system/enterprise is complex. Safe and quick evacuation of combat casualties to an appropriate level of care facilities is the key concern of any emergency medical evacuation (MEDEVAC) [15]. There are three main categories of MEDEVAC, forward, tactical, and strategic. In forward MEDEVAC, the patient is transported as soon as feasible from the site of injury to the most appropriate care facilities, not necessarily the nearest facility. Accordingly triage of patients playing a key role in this step. During forward MEDEVAC, it is of paramount importance that a casualty is provided appropriate care according to the 10-1-2 Timeline, a set of predetermined clinical time frames (i.e., bleeding control within 10 min, advanced resuscitative care within 1 h, and damage control surgery within 2 h). Tactical MEDEVAC concerns the transport of patients between different MTFs, generally, care levels increase from lower to greater. This evacuation happens within a Joint Operational Area. Strategic MEDEVAC is the movement of ill or wounded personnel from the Joint Operational Area to a facility in their own country or to another safe location outside the theater [15,17].

Armenia gained experience in medical evacuation during previous military conflicts in Nagorno-Karabakh between 1991–1994 and in 2016. From the earliest days of the 2020 Nagorno-Karabakh War, many highly qualified physicians even from Armenian diaspora, including maxillofacial surgeons, voluntarily deployed to Nagorno-Karabakh and border regions of Armenia in close proximity to active combat zones. Their role was to provide urgent and specialized care and to organize the medical evacuation of the wounded in accordance with the aforementioned MEDEVAC system.

As a result of this coordinated approach, patients arriving at definitive care facilities, including our hospital, presented with appropriately managed wounds and stable hemodynamic and respiratory status.

High-energy ballistic and avulsive injuries to the face represent some of the most complex challenges in modern reconstructive surgery [5]. Maxillofacial injuries represent a significant proportion of war-related injuries; however, their characteristics have evolved over the decades as new types of weapons and battlefield strategies have been introduced [2,3,10,13,18,19]. High-energy ballistic injuries to the craniomaxillofacial region create complex, contaminated composite defects with an evolving zone of injury and high risk for infection, soft-tissue loss, and functional compromise [5].

As reported Prysiazhniuk O with coauthors in their study the predominance of high-velocity blast injuries in this cohort was associated with concomitant maxillofacial trauma to other organs and systems in 82% of patients [3]. The most frequently associated injuries were to the extremities (49.9%) and the brain (32%), both of which significantly impacted prognosis and posttraumatic outcomes. Ophthalmic trauma, frequently associated with midfacial fractures and defects, is another major concern; 50.1% of maxillofacial trauma patients in this study suffered eye injuries, with 9.2% experiencing eye loss [3]. In presented data concomitant with maxillofacial other organs and systems trauma was observed in all patients. Extremities injuries were the most frequently associated injuries and were found in 78 % cases. Eyeball injuries concerning evisceration were reported in 9.8%, which is in accordance with Prysiazhniuk O et. al. data (2025). In the Syrian War, approximately 63% of maxillofacial injuries were accompanied by extremity or other organ injuries, reflecting the widespread impact of shrapnel, missiles, or bullets [20]. Burns was evaluated in 82.9% of reported cases in presented study which is according with most of blast injury studies [3,5,6,10,13]. The subgroup analysis further supports the clinical observation that burn-associated injuries and extensive soft tissue defects are key determinants of delayed healing and the need for secondary reconstruction. These findings highlight the importance of individualized treatment strategies and reinforce the role of early identification of high-risk patients. Hearing loss was reported also in 92.2% of military service members and veterans who served in the recent Iraq and Afghanistan conflicts [21]. All patients exhibited signs consistent with blast-related acoustic neuritis. This finding

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underscores the critical role of multidisciplinary cooperation in the treatment and rehabilitation of war-related injuries.

The literature remains heterogeneous and largely limited to case series, with inconsistent definitions and outcome reporting, leaving persistent uncertainty regarding the optimal timing and sequencing of reconstruction, objective debridement endpoints, and comparative outcomes across reconstructive strategies [5]. All patients with combined or complex midface blast fractures in presented study have undergone the early wound revision and final reconstruction after admission to our hospital. Only patients with nasal and lips amputations and one patient with severe combined facial burns (III^0-IV^0) have several step operations for soft tissues reconstruction. The paper by Pepper T., with coauthors (2026) encouraged surgeons to move away from cautious traditional methods of management, with delayed reconstruction, and, instead, favor treatment with earlier internal fixation, while urging close attention to wound bed preparation so that early reconstruction has a higher chance of success [5].

All fractures reconstructions in presented study demonstrated stable outcomes without implant-related infection or failure. No cases of postoperative osteomyelitis or bone sequestration were observed during the 5-years follow-up. This is in accordance with Pepper et al., consensus recommendation, where was reported that early definitive bony reconstruction within 10–14 days leverages the window during which the soft-tissue envelope remains extensible and regional vascularity favors graft/flap perfusion. Delays beyond this period increase scar contracture, distort facial buttresses and occlusion, and complicate both surgical access and aesthetic outcomes.

The long-term outcomes (5 years) have demonstrated progressive thinning of soft tissues over titanium meshes resulting in aesthetic imbalance especially in the zygomatico-orbital zones in presented study. Mechanisms: chronic irritation, pressure necrosis, foreign body reaction, reduced vascularity and key risk factors are thin overlying soft tissue, infection, patient comorbidities [22,23]. Further prospective and multicenter studies are required to validate these findings and to develop standardized treatment protocols.

Conclusions

Modern warfare imposes a profound burden on society, particularly affecting young individuals who face long-term functional and psychosocial consequences of trauma. Drone-induced blast injuries of the midface demonstrate distinct characteristics compared to conventional gunshot injuries and can often be managed with early definitive reconstruction, allowing restoration of anatomical integrity. However, soft tissue defects—especially of the nasal and perioral regions—remain challenging and frequently require staged reconstruction.

From a clinical perspective, early surgical management combined with individualized reconstructive planning is essential. Long-term follow-up is critical for addressing soft tissue deficiencies and optimizing aesthetic outcomes. Future research should focus on developing standardized treatment protocols and improving reconstructive strategies to enhance long-term functional and psychosocial recovery.

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Institutional Review Board Statement: The study was conducted in accordance with the Declaration of Helsinki, and approved by the Ethics Committee of Yerevan State Medical University (IRB No. 05/2026). Patient data were anonymized, and confidentiality was strictly maintained.

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

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Data Availability Statement: Data available from the corresponding author upon reasonable request.

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Conflicts of Interest: The authors declare no conflicts of interest.

Abbreviations

The following abbreviations are used in this manuscript:

CT	Computed tomography
MME	Military medical evacuation
MEDEVAC	Medical evacuation

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